# ON THE MICROSCOPIC CRYSTALS CONTAINED IN PLANTS.

BY W. K. HIGLEY.

IT has been the custom to call all crystals that occur in plants, whether in the cell contents, the cell-wall or even the non-microscopic crystals that are found in the outer portions of plants, by the common name "raphides," no matter what the form may be. And while giving this general name to their form, a much more general chemical composition was given, viz: oxalate of lime; and for a long time they were all supposed to have had this composition, and even up to the present day many writers have considered them thus. The decision of some seems to have been based on the analysis of the inorganic matter of one crystal-bearing plant, which proved to have the above composition, and in drawing their conclusions they considered that all crystals of apparently the same crystalline form, were of the same composition. But it is difficult to tell, at all times, the exact crystalline form, as different forms sometimes resemble each other very much. And as the form may vary, so may the chemical composition. Crystals of some form seem to be nearly or quite universal; on close examination they may be found in some part or parts of the majority of plants. In some plants they are only found in a certain position and of one form, while in others they may occupy several localities of the plant, and have as many forms. But the position and form often vary so much that it has been recommended by some authorities that they be made a family, and in some cases a generic distinction in the study of systematic botany.

Prof. Geo. Gulliver, while making dissections under the microscope for the purpose of comparing the relations between the structure of plants and animals, made note of every case, in the examination of plants where raphides or other crystals occurred, and he says: "It was not before a large accumulation of my notes had been examined that crystals were thought of in this point of view; for they had not even been particularly looked after, and were merely noted whenever seen, long before their significance as characters were suspected. But when every one of these notes on raphides had been picked out, it was very unexpectedly discovered that the plants in which they occurred would sometimes come under certain orderly arrangements.

Thus not a single species belonging to the order Onagraceæ or Galiaceæ was without a note of raphides, while in no single instance were these acicular crystals noted in the next allied orders." A converse example is then given. He then proves by more extended experiments that raphis-bearing is essential throughout the lives of certain species. By this and other experiments that I might mention, it is shown that the form and position of microscopical crystals in plants may be used as a distinctive character between orders especially, and perhaps to a certain extent, between genera and species (?). Plant crystals as a character would only be of benefit to the botanist who had at hand a microscope that magnified at least a hundred and twenty-five diameters. Hence the objection to making them a means of identifying plants in our works on systematic botany.

As to the history of crystals, Lindley states that they were first seen by Rafn, who found them in the milky juice of some species of the family Euphorbiaceæ, and that they were afterwards seen by Jurine in the leaves of *Leucoium vernum* and elsewhere.

Edwin Lankester, M.D., writing on raphides, credits Malpighi with the discovery of crystals in plants, who found them in a species of Opuntia, and he says, further, that they were afterwards described by Rafn as occurring in the milky juice (latex) of some plants belonging to the family Euphorbiacæ, and that Jurine soon after found them in the leaves of *Leucoium vernum* as stated by Lindley.

Raspail seems to have been the first person who studied crystals with their chemistry in view, at least he was probably the first to demonstrate that some of the crystals were composed of calcic oxalate.

John Quekett, in a paper written in or about the year 1852, also gives the credit of the discovery to Malpighi, and says that they were subsequently described by Jurine and Raspail, as stated above.

Prof. Gulliver says that the raphides so early mentioned by Rafn in the Euphorbiaceæ were only the starch-rods which he (Gulliver) described as having found in the latex of the British Spurges.

Crystals should be divided into (at least) three classes and these seem to cover all the ground that was formerly covered by the name "Raphides." They are as follows:

1. Raphides.
2. Sphæraphides.
3. Crystal prisms.

1. *Raphides.*—The term raphid is from the Greek ῥαφίς, a needle, and was formerly applied by De Candolle to crystals resembling a needle in form.

Prof. Gulliver gives the following definition of the term: "These are slender needle-like crystals with rounded, smooth shafts, vanishing at each end to a point, from about ten to fifty or more lying parallel together so as to form a bundle, which partially fills a cell or intercellular space."

I have never been able to find over thirty in one cell, and generally from five to twenty-five. The cells which contain them are generally elongate, or quite oval. To obtain these crystals in a bundle and still have a thin section fit for microscopical work, a steady hand and great care are required, as they are easily disturbed, when they will be seen scattered in every direction. Often on slight pressure they are seen to escape, one by one, quickly from one or both ends of the cell. When this occurs they are then known as "Biforines." The bundle of crystals is very loose and might be compared to a bundle of needles.

The genus *Trillium* affords a good example for the investigation of these crystals, and still better the species of the family *Araceæ*, with one exception which will be mentioned soon. In this family the raphides are found in great abundance and are about the largest that I have seen. As the plants of this order are very common, any one may examine them at pleasure. They may be found in any part but are best seen in the stem.

2. *Sphæraphides.*—This word is from the Greek σφαῖρα, a sphere or globe, and ῥαφίς, a needle or pin. "They are more or less rounded forms made up of a congeries of crystals, many of which are prisms, often acicular." As they often have points extending in all directions from the main body of the crystal, they appear rough and frequently stellate; they are generally found regularly placed, one imbedded in the substance of each cell. A collection of cells containing these crystals is known as a "sphæraphid tissue."

The flower parts of the geranium serve as a good field for observing them. These crystals are very common and are found in connection with raphides in the family Vitaceæ. But the best place to examine them is in the family Cactaceæ. These crystals as well as the next class were formerly known, incorrectly, under the common name "Raphides."

3. *Crystal prisms.*—These are "acicular forms with well-marked faces and angles both on the shafts and tips." They are found imbedded in the tissue of the plant and are never seen in bundles or loosely packed together, or single in a cell or intercellular passage. I have found as many as five of these crystals imbedded close together in certain tissues, but generally only one. They vary much in size but are generally much larger than raphides from which they may be easily distinguished. The family Compositæ furnish about the best field for the examination of this class of crystals, but they are much less common than the other forms of crystals.

My own observations and experiments have been, at present, mostly confined to the natural orders Araceæ, Vitaceæ and Compositæ. I examined the first two orders especially, as they abounded in crystals, and this gave me a better opportunity to examine into their chemical composition with more sure and satisfactory results.

In examining each specimen for the composition of the crystals, I first made the test under the microscope as far as possible, and in the case of inorganic crystals incinerated the substance and analyzed the residue. Of course from this analysis it is not possible to state the exact composition of the crystals, whether they are, for example, acid or neutral salts; but we are able to state with certainty what the elements are that enter into the crystal. And at times and under certain conditions, and also by analogy, the exact composition may be ascertained; for example, if on examining the tissues of a plant octahedrons are found, and if under the microscope they do not effervesce with acetic acid, but do with stronger acids, and if after incineration we find on analysis calcium and carbonic acid, we may conclude with certainty that these crystals are composed of calcic oxalate. However, other acids than the one just mentioned do occur, as phosphoric and carbonic acids; the former I tested for under the microscope in the following manner: obtaining as large a field as possible of the crystals, I added a drop of hydrochloric acid and heated the slide slightly and then added a small amount of molybdate of ammonia; heating the slide again and allowing it to stand for some time, I placed it under the microscope, when, if any phosphoric acid was present the characteristic crystals of phospho-molybdate of ammonia would appear. These crystals

are stellate forms consisting of four or six points, and have a yellow color. *This test requires care, as too much heat seems to dispel the crystals.*

The latter (carbonic) acid I detected in the usual manner with acetic acid.

The three acids mentioned above are the only ones that I found. Dr. Gray, in his "Structural and Physiological Botany," page 60, reports sulphuric acid.

The tests applied for the base were the same as those given in Douglas and Prescott's "Qualitative Analysis," but the only base found was calcium. The methods of testing given above were followed in nearly all cases. Where there is any change it will be mentioned in its proper place.

I will now give the results of my own work, commencing with the order Araceæ; in this order the raphides are abundant and large, and the cells that contain them are much elongated. The bundles contained from ten to twenty-eight crystals. The number was noted in twenty specimens and the average, twenty-five, taken from the results. Raphides were found in all parts of the plant *Arisæma triphyllum*; they varied some in size, but were, on the average, about $\frac{1}{100}$th of an inch long and $\frac{1}{10000}$th in diameter. The raphis-cells were very large and elongated and easily distinguished from the surrounding cells.

Dracontium, another species of the same genus as the above, showed no material difference in the position, size and number of the crystals from the first species.

In *Symplocarpus fœtidus*, or skunk's cabbage, the crystals were as common as in Arisæma, but were, on the whole, somewhat larger, and were found, as in the above species, throughout the plant. The raphis-cells of this plant were about $\frac{1}{80}$th of an inch in length and $\frac{1}{1000}$th in diameter. Some of the crystals appeared to be biforines, which I did not observe to be the case in any other species of this order. Thus if the odor of this plant can be overcome, it furnishes a good field for work upon this subject.

In *Acorus calamus*, or sweet flag, I was not able to find a single raphid, and as far as I am able to find articles upon the crystals of this family, none have ever been reported, but time and again students have been disappointed in not finding them. This genus is thus marked off from the rest of this family, although agreeing with the family characters perfectly in other particulars. Dr.

Gray, in his systematic arrangement of plants, places this genus in the family Araceæ, but Lindley, on account of there being no raphides, and as the general characters of the plant would not permit of its being placed in any other family, places it in a family by itself, calling it Acoraceæ. This genus contains but few crystals of any sort. On examining a number of specimens I found only a few crystal prisms, which effervesced and dissolved with hydrochloric acid and were probably oxalate of lime. With the exception of the genus Acorus the crystals mentioned in this family showed with certainty that they were composed of phosphate of lime when the chemical tests were applied both under the microscope and also to the incinerated residue.

[*To be continued.*]

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## EDITORS' TABLE.

EDITORS: A. S. PACKARD, JR., AND E. D. COPE.

—— The late meeting of the American Association for the Advancement of Science at Boston, under the presidency of the Hon. L. H. Morgan, was a very successful one. There was a large attendance, most sections of the United States and Canada being represented. A considerable number of papers of a high order of merit were read. Propositions for a precise and convenient division of the work of the Association were considered, and a report on the subject may be expected at the next meeting.

The arrangements made by the local committee were excellent, and the most convivial member could not complain of any deficiency of receptions or "lunches," either as to quantity or quality. The excursion to the White mountains was replete with interest to the geologist, the more so as it was accompanied by the State Geologist of New Hampshire, Prof. Hitchcock.

Of the addresses of the officers, we refer to two as especially interesting to our readers, viz: those of Prof. Barker, the retiring president, and of Mr. Agassiz, vice-president in charge of Section B. The former was a general exposition of the present state of knowledge of the physics of life. The chemical nature of the respiratory and digestive functions, and the dynamic characteristics of muscular contraction were passed in review. The character of nervous te'egraphy was discussed, and its relations to mental phenomena considered. The conversion of force in reference